REPORT

OF THE

Muscle Shoals Committee

OF THE

American Farm Bureau Federation

PUBLISHED BY

American Farm Bureau Federation
58 East Washington Street
CHICAGO, ILL.

REPORT

OF THE

Muscle Shoals Committee

OF THE

American Farm Bureau Federation

CONTENTS

REPORT OF THE MUSCLE SHOALS COMMITTEE OF THE AMERICAN FARM BUREAU FEDERATION.

To The Executive Committee, The American Farm Bureau Federation.

Gentlemen:

Your Committee which was appointed to investigate the Muscle Shoals project has performed that duty in the double capacity of personally inspecting plants and by collecting the available information from all sources for your consideration. We beg leave to report as follows:

I. INTRODUCTION.

Since the signing of the armistice on November 11, 1918, many of the operations in which the Federal Government found itself engaged prior to that date have been discontinued on account of a peace-time basis not requiring certain war expenditures and activities to be continued. It is with a great degree of gratification that all citizens see our Government gradually discarding all expenditures and all projects that were purely incidents of the great war. There are a few undertakings, however, the necessity for which had been seen before our entrance into the war, that deserve the fullest consideration both by urban rural citizens to ascertain whether or not it is best to continue them indefinitely for the good of the general public.

There is no problem of conservation more vital than that of preserving the fertility of the soil of our country. Those who dwell in cities are essentially as much interested in this task as are those who actually till the fields. The food of our nation must come largely from a well-preserved soil, and that soil necessarily must carry, either naturally or in the form of fertilizers, the proper nitrogen content. It has been said repeatedly that agriculture in its broadest sense has been neglected by the Federal Government in various ways. It is hoped that a genuine national policy of soil conservation and food production will be furthered at this time by taking such action relative to securing an adequate and economical supply of nitrogen as is recommended elsewhere in this report.

The outstanding war-time project which can be continued as a peace-time undertaking while at the same time retaining all its war-time functions for public safety is the Muscle Shoals project in Alabama. On account of the magnitude of this project not only in size but in importance to the whole nation, your Committee has thought it well to report in a comprehensive way and at some length. For clarity of presentation the subject matter has been divided into eleven parts with frequent comment by the Committee and with two very definite recommendations at the conclusion of the report.

II. WHAT WAS SEEN AT MUSCLE SHOALS

(a) The Tennessee River at Muscle Shoals, from which power is to be taken to operate the nitrate plants and for other purposes, is as large, taken at the mean or average flow, as is the Ohio River at Cincinnati, Ohio, the Mississippi River at Dubuque, Iowa, or the Missouri River at Omaha, Nebraska.

(b) The banks of the Tennessee River at Muscle Shoals are of such height that a hundred foot head of water may be held without building any retaining walls or dikes whatever except the dam proper.

(c) The pool formed by the dam will extend for a distance of 15 miles upstream, and the total amount of land flooded or damaged by the water is 9,000 acres. This area has been bought and paid for by the Government with a very few exceptions where condemnation proceedings are now nearing completion. This land was secured at an average price of less than forty-five dollars per acre.

(d) The Wilson Dam is about one-third completed and more than one-third paid for, as will be seen when the immense expenses attached to the preparatory work are considered, which expenses do not again have to be met in finishing the project.

(e) Two sections of the Wilson Dam—one at the north bank and one in the center of the river on an island—are partially completed. There yet remains for construction on these sections the discharge gates at the top and the roadway above the gates.

(f) The foundation is laid for a large portion of the rest of the dam and the protecting coffer-dams have been removed.

(g) The excavations for the power plant and south section of the dam have been made under protection of an immense coffer-dam which will permit work to be carried on in that section if the work is not too long delayed.

(h) A construction bridge carrying several railroad tracks, and supporting seven derricks, each capable of lifting ten tons has been built.

(i) Twenty-five miles of railroad track have been laid to haul supplies, rock, sand, cement, concrete, etc.

(j) Several locomotives, some of which weigh 65 tons each, have been used constantly in hauling material to the concrete mixers and thence to the dam.

(k) Three mixing plants with capacity to keep all the other equipment moving at full speed have been installed, one on the island near the center of the stream, one on the north shore and one on the south shore.

(l) A large construction camp has been erected with individual homes for married men, bunk houses and mess buildings for single men, and administration offices and residences for the official corps.

(m) The Wilson Dam is 4,100 feet long; its base, which is sunk 12 to 15 feet into the solid rock of the river bed, is 160 feet

wide; its height from the original river bed to the bottom of the overflow gates is 80 feet; and to the roadway on the top 120 feet. This structure when completed will be the largest single piece of monolithic concrete construction in the world.

(n) Two locks for navigation purposes are being constructed at the north end of the dam, each one having a lift of 45 feet, and with other dimensions adequate to accommodate the largest river craft.

(o) Nitrate Plant No. 2 at Muscle Shoals stands today fully equipped and capable of producing 110,000 tons per annum of ammonium nitrate.

(p) The site on which this plant is built comprises approximately 2,000 acres.

(q) At the height of operations on this plant 20,000 workmen were employed. It was built in one year, and the first ammonium nitrate was produced one day less than a year from the time of starting construction work. At that time 90% of the mammoth plant was finished, and today it is 100% complete for the production of fixed nitrogen.

(r) The steam power plant was built so that Nitrate Plant No. 2 could begin production without waiting for the completion of the Wilson Dam which was expected to take approximately three years. This steam plant produces nearly as much electrical energy as any other steam plant ever built, and contains one steam turbine unit with electrical generators which generates 60,000 kilowatts or 80,000 horse power—being one of the largest turbines ever constructed and operated. In addition there is place for a smaller unit which would be capable of producing 30,000 kilowatts, or 40,000 horse power, making a total horse power for the entire steam power electric plant when completed of 120,000 horse power, which is ample to operate the electric furnaces in another part of the plant.

(s) The boiler room of this immense plant comprises a battery of 15 units each rated at 15,000 horse power. These boilers when running full capacity consume approximately 1,500 tons of coal each day, which fuel is dumped from the cars on overhead tracks into vast bins, and thence fed into the furnaces by automatic stokers without being touched by human hands since leaving the mine. The three stacks to provide draught for these furnaces vary in height from 275 feet to 300 feet, and in diameter at the base from 23 feet to 26 feet.

(t) The kiln room where the lime rock is burned to lime contains seven cylindrical kilns which turn slowly, and which are heated by a blast from finely ground coal. These kilns are of steel, lined with fire brick and are so mounted that the lime rock when placed in the higher end will gradually travel the entire length of the kiln, which is 125 feet and emerge from the lower end as burned lime. Approximately 1,500 tons of lime rock can be burned in a day, which shrinks in the form of burned lime to about one-half that weight.

(u) The electric furnace building where the burned lime and coke are fused electrically into carbide, as the first step toward fix-

ing nitrogen, is about 1,000 feet long and contains twelve electric furnaces, each of which requires 10,000 horse power for its operation. Only ten of these furnaces are expected to operate at any one time, leaving two for repairs at all times. The giant electrodes through which the electrical current passes and which furnish the heat for fusing the burned lime and the coke, are subjected to such terrific heat that they have to be renewed every three days. This shows the necessity for extra furnaces. Each furnace produces 50 tons of carbide per day, or a total for the ten furnaces of 500 tons. Practically all work of handling the materials used in Nitrate Plant No. 2 is done by machinery. However, these electrical furnaces must be fed by hand in order to fill the blow holes that appear in the molten mass, which unless filled by shovelfuls of coke and lime, cause rapid radiation of heat.

(v) The plant where nitrogen is taken from the air by the liquid-air process is many times larger than any similar plant ever constructed. In this plant nitrogen testing 99.9% pure is secured in volumes aggregating 500,000 cubic feet every hour. The oxygen and a small part of the nitrogen are returned to the atmosphere.

(w) The oven building contains 1,536 ovens in which the nitrogen is fixed, or caught, in the carbide. Each oven is about three feet in diameter and five feet deep, holding approximately 1,600 pounds of carbide. This charge is heated, electrically, to white heat and the nitrogen from another building is forced through it and is caught. The product from these kilns is cyanamid or lime nitrogen, and contains 21% of fixed nitrogen.

(x) The autoclave building contains 56 cylindrical steel autoclaves, which are steam-tight vertical boilers with agitators to stir the powdered cyanamid in order to drive off the ammonia gas. Each autoclave holds four tons of the powered cyanamid and it takes about an hour and one-half to get the fixed nitrogen out of the cyanamid and into the form of ammonia gas in order later to convert it into ammonium nitrate for military or agricultural purposes.

(y) Many smaller buildings, each of which is indispensable in the complete process through which lime, coke and air must go in order to get nitrates for either explosives or fertilizers, are component parts of the gigantic whole of Nitrate Plant No. 2. In all there are about thirty buildings as units in this plant.

(z) Nitrate Plant No. 1 is a much smaller plant than No. 2, and is designed to secure nitrogen from the air and fix it for military or agricultural uses by an entirely different process than the one used in No. 2. It has never operated on a commercial or practical scale but is completely equipped for operation.

Comment by the Committee

The information given above contains some remarkable facts which your Committee feels free to comment upon, not in the way of specific recommendations but rather that you may be informed what relation these facts bear to our welfare as citizens and as farmers.

(a) That the Wilson Dam contains the possibility of developing a hydro-electric plant far in excess of any yet contemplated in America—with the exception of Niagara Falls—is evidenced by the fact that it will maintain a head of water almost one hundred feet high and has the volume of flow referred to in II (a), whereas the great Keokuk Dam across the Mississippi River holds only a forty-foot head of water.

(b) There seems to have been no graft in the Government's acquisition of the land which will be inundated. The average price paid for this land seems to your Committee to be entirely within reason; furthermore, there appears no likelihood of litigation subsequent to such inundation.

(c) Millions of dollars, undoubtedly, have been spent in the preparatory work which necessarily had to precede actual construction. Now that all this preparatory work has been done, and paid for, it is the thought of your Committee that legislation and appropriations should be provided for in Congress to avoid the loss of all this preliminary construction.

(d) The engineers in charge of construction work on the Wilson Dam state that although only about one-third of the permanent work has been completed more than one-third of the total expense has been met, on account of the cost of the preparatory work.

(e) Your Committee is impressed with the necessity for a resumption of building operations on the dam, which were discontinued in April on account of a lack of appropriations.

(f) It is needless to state that the great steam plant which is capable of running all of Nitrate Plant No. 2 was built only to operate the plant until the Wilson Dam could be completed and furnish a cheaper power. The steam plant should now be considered as an auxiliary power plant to the hydraulic development, as nitrates can be made much cheaper with hydraulic rather than with steam power.

(g) Your Committee desires you to remember that in the fixation of atmospheric nitrogen in the lime-nitrogen process some substance must be made that will soak up nitrogen somewhat as a sponge does water. Carbide, which is made by fusing lime and coke in an electric furnace, is the material used in Nitrate Plant No. 2. However, it is a chemical reaction that takes place and not a physical one.

III. AVAILABILITY OF NITRATE PLANT NO. 2 FOR MANUFACTURING FERTILIZERS.

It is a generally recognized fact that up to a certain point the manufacturing of nitrates for military or for agricultural uses follows a common course. This is true whether the nitrates are atmospherically fixed or obtained otherwheres. In this report, of course, we are primarily concerned with the form of nitrates which is secured from the air, as the other forms have been longer used and more fully understood. There are three great sources of com-

mercially used nitrates. First in tonnage is Chilean nitrate; then the ammonia secured as a by-product from coke ovens; and finally atmospheric nitrogen, which until recent years has been a dream of scientists but is now very practical, and is rapidly forging ahead in the tonnage produced. To these three may be added a fourth source which is the use of legumes in fixing atmospheric nitrogen and which farmers are coming more and more to value. This is nature's way of taking fertilizer out of the air and placing it in the soil in tubercules on the roots of legumes. Man has recently learned how to do the same thing mechanically and chemically.

In the fixation of atmospheric nitrogen, either for military or agricultural purposes, several steps are necessary before we have a commercial product. In order that there may be a clear understanding of the process used in Nitrate Plant No. 2 at Muscle Shoals, an effort will be made, herewith, to detail in non-technical and comprehendable terms the various stages in the process.

1. Lime rock is burned into lime and mixed with dried coke which has been finely powdered.

2. This mixture is melted together in electric furnaces which generate a heat exceeding 1500 degrees centigrade. The product of these furnaces is known as carbide which is the same product that is used in all acetylene lighting plants.

3. The carbide, after cooling, is ground through various machines until most of it will pass through a screen having 200 meshes to the square inch.

4. Air being formed of a mixture of nitrogen and oxygen, and only the nitrogen being needed for this process, the two gases are separated, first, by compressing and cooling the air until it becomes liquid, then distilling this liquid to separate the two gases much in the same way that alcohol is separated from water in making spirituous liquors.

5. This nitrogen is then blown gently through ovens in which the powdered carbide has been heated, electrically, to a white heat, and the result is that the carbide catches or fixes the nitrogen, in a manner very similar to the "soaking up" of water sprayed into a box of sand.

6. Now we have lime-nitrogen (cyanamid) which is the first form of air-fixed nitrogen either for military or agricultural uses. It carries about 21% fixed nitrogen, and is directly available as a fertilizer, but has some limitations in its use.

7. The lime-nitrogen after being ground to a fine powder is treated to a bath of steam and a weak alkali, under pressure of about 150 pounds to the square inch. This causes a gas to be formed known as ammonia.

8. About half of this ammonia gas is mixed with air and by being passed through an electrically heated platinum gauze the gas-air is heated to 600 degrees centigrade. When this superheated mixture is suddenly subjected to a low temperature it begins to change to nitric acid, much as the moisture in a cloud condenses

into rain drops when struck by a cooling wind. The cooling process is continued until all the ammonia is changed into a 50% nitric acid.

9. The other half of the ammonia gas is then forced into tanks which hold the nitric acid and is absorbed by the acid. This gives us ammonium nitrate in liquid form. This process is comparable to the method of making carbonated water in which a gas is forced into the water and held there.

10. This liquid ammonium nitrate is subjected to heat, and evaporation removes all the liquid, leaving a pure ammonium nitrate which when cooled in revolving pans in which there are stirring paddles, gives us a grained powder not unlike sand in appearance and which carries 35% of nitrogen. We all know that sorghum when subjected to the proper heat for too long a time crystallizes into sugar. A very similar crystallization process happens in the case of this liquid ammonium nitrate.

11. If sulphuric acid is substituted for nitric acid in the process described under paragraph 10, we will have ammonium sulphate instead of ammonium nitrate. Sulphuric acid to use in the production of ammonium sulphate can be purchased or made in the plant. When the Government plant at Nashville, Tennessee, for the production of explosives was disposed of at the close of the war part of its equipment for the production of sulphuric acid was retained and shipped to Muscle Shoals and is now available for installation at Nitrate Plant No. 2 if it is found necessary to do so.

12. Either one of the above named products is readily adaptable to fertilizer uses.

Comment by the Committee

1. Your Committee desires to suggest that in dealing with the whole proposition of manufacturing nitrates, for military or agricultural uses the location of the plant is of prime importance. Nitrate Plant No. 2 at Muscle Shoals in connection with the Wilson Dam, has the following remarkable list of advantages in location:

(a) Practically inexhaustible quarries of the purest lime rock are easily accessible. The present quarries are only twenty-eight miles removed.

(b) Coke, which combined with burned lime in the early stages of the process used at Nitrate Plant No. 2, is produced in large quantities in the coal fields of Tennessee and can be transported quickly to Muscle Shoals. The greatest coke-coal beds in the nation lie between the Tennessee and the Ohio Rivers.

(c) The greatest deposits of raw phosphate rock in America are in Tennessee, which adds the possibility of using phosphate rock in electric furnaces and producing phosphoric acid and available phosphates as well as nitrates.

(d) Coal beds of immense proportions almost surround Muscle Shoals, all within easy hauling distance. Great quantities of coal are needed to burn the lime rock as well as to operate the great steam power plant as an auxiliary to the water power. There seems to be no need of Nitrate Plant No. 2 producing its own coke as this product can be purchased economically from coke ovens already operating. The same statement may be true relative to sulphuric acid in making ammonium sulphate.

(e) The Tennessee River is a navigable stream and so offers cheap transportation, both for supplies needed at the plant and for products shipped therefrom, to the whole Mississippi, Missouri and Ohio River systems.

(f) Muscle Shoals is nearly in the heart of the great fertilizer using section of our nation, but is also situated agriculturally somewhat near the center of the whole country.

(g) Muscle Shoals is far enough inland to be considered in the safety zone for war-time. That is, if an invading army should land on the Gulf shore, the distance to Muscle Shoals is so great that this plant would be comparatively safe, and could continue making nitrates to repulse the enemy.

(h) With the immense water power development incident to the completion of the Wilson Dam there is the certainty that much of the electrical power can be sold for industrial uses other than operating Nitrate Plant No. 2. Within easy transmission distances of Muscle Shoals lie the metropolitan centers of Birmingham, Alabama; Memphis, Tennessee, and Chattanooga, Tennessee, not to mention others of considerable importance. The great coal operations of this territory may be expected to become users of electric current, too.

2. It will be permitted the Committee to remark that the cheapness of any fertilizer depends to a very large extent upon the ease and simplicity with which it is manufactured, and that the more frequently it is handled or treated in the process of manufacturing the more expensive it becomes. Consequently the cheapest fertilizer which is capable of being produced at Muscle Shoals is the lime-nitrogen (cyanamid). This product is a good nitrogenous fertilizer when used by itself but carries much more nitrogen than the usual mixed fertilizer and must be used carefully. When only a nitrogenous fertilizer is needed, lime-nitrogen gives as good results as are secured by any other form of nitrogen, but is somewhat slower in its availability. However, in mixed fertilizers the lime-nitrogen, if used in too great quantities, causes the phosphates to become less soluble, and hence less available as plant food, on account of the lime reacting unfavorably on the phosphates. It is fair to state, though, that the chemists seem nearly to have a treatment for the lime-nitrogen which will remove this undesirable characteristic. It is entirely to be expected that with further experiment these difficulties will be entirely overcome.

When lime-nitrogen is advanced through its subsequent stages and is changed into ammonia gas, then to nitric acid, and finally into ammonium nitrate, or ammonium sulphate it can be readily used, either alone or in mixed fertilizers. All these later stages, as above stated, increase the cost of the nitrogen content of whatever product is manufactured.

3. In this report but little mention will be made of Nitrate Plant No. 1. The process designed to be used in that plant is entirely different from the one in No. 2 and although it is comparatively a simple chemical process the mechanical difficulties have been such as to offer great difficulties to a practical operation of the plant. Your Committee desires the permission to suggest, however, that its faith in the ability of our chemists is so great as to justify us in holding Nitrate Plant No. 1 intact ready to operate

when the difficulties shall have been overcome. Accordingly, you will note in one of the two definite recommendations at the end of this report that your Committee has incorporated both nitrate plants in the same recommendation.

IV. NECESSITY FOR AN INCREASED NITROGEN SUPPLY.

The world's supply of nitrogen comes from two great classifications, the organic and the inorganic. The organic nitrogen is supplied by such commodities as tankage, dried blood and cotton seed meal. These products are rapidly being transferred from the fertilizer field to the stock-feeding industry. It has developed that the feeder of livestock can compete in the purchase of these products much to the disadvantage of the feeder of soils who desires to use them as fertilizers. Their use as fertilizers is rapidly ceasing, but a constant increase is noted for these products as stock food. So we may as well not consider these organic nitrogenous products in summing up our available fertilizer supply. Their use is comparatively negligible as plant food.

Our inorganic nitrogen comes almost wholly from three sources. First in importance, as measured by the tonnage used is the Chilean nitrates. Next in tonnage produced comes the coke ovens from which a form of nitrogen is secured as a by-product. In recent years, a third source has been developed in the fixation of atmospheric nitrogen. The development of methods, especially the lime-nitrogen or cyanamid process for fixing, or capturing, the nitrogen that is in the air, has assumed such importance in recent years, not alone in our country but in several other nations, as to justify the statement that the world's increasing demand for nitrates, in industry, for military purposes and in agriculture, will be met largely by the fixation of atmospheric nitrogen.

A review of the present situation as regards the Chilean nitrates and the by-product from the coke ovens will serve to confirm the statement just made. In the period between 1913 and 1920 the production of Chilean nitrates increased only about 28 per cent, although the whole world was seeking nitrogen. This may be accounted for, partly, by the falling off of the nitrate content in the Chilean product which requires the handling of a much larger tonnage of the raw material to satisfy the world needs. The available nitrogen in the Chilean product has dropped from nearly 30 per cent where it was in former years to less than 20 per cent now. This signifies, no doubt, that the best beds of the nitrate deposits have been used. Also, it may seem that inaccessibility of the remaining beds makes production much slower than was formerly the case. Whereas, a laborer years ago was able to produce more than 70 tons per year, now the same laborer is producing approximately 55 tons.

The production of nitrogen as a by-product from coke ovens is altogether dependent upon the growth of the steel industry. Coke is produced primarily as an adjunct to the production of steel, and cannot profitably be produced in quantities in excess of the require-

ments of the steel furnaces. In other words, it cannot be produced simply for its by-products which are nitrogen, tar, gas and oil. Somewhat more than half the coke of our country is produced in ovens which can save the by-products, but the old-fashioned bee-hive coke ovens are not being superceded although they produce nothing but the coke, and do not save the by-products. This may point to the conclusion that as more ovens are built, or old ones remodeled, the determining factor in their operation is the production of coke and not the by-products. So we should not expect the coke industry to lead out in nitrogenous production when its development is dependent upon the growth of another industry—steel. The increase in the production of nitrogen from these coke ovens in the period between 1913 and 1920 was slightly more than 19 per cent.

But the statistics as usually given representing ammonium sulphate production from the by-product coke ovens do not state the exact conditions from the fertilizer standpoint. To look at the statistics one might think that in 1918, for instance, there were produced 408,237 tons of ammonium sulphate available for use in agriculture. This is by no means the case for this figure represents the amount of sulphate of ammonia that would have been produced in 1918 if all the ammonia in all forms that was obtained from the by-product ovens had been made into ammonium sulphate. The facts are that nearly half of this amount given as ammonium sulphate is never available for agriculture. In 1918 the actual production of ammonium sulphate was 218,194 tons, according to the United States Geological Survey report. As a general average, 45% of the so-called ammonium sulphate represents simply the production of ammonia in gaseous form which is absorbed in water and is sold as aqua-ammonia for refrigeration and other industrial and domestic purposes and is never made into ammonium sulphate at all. The demand for ammonia in this form is met first by the by-product coke ovens and what is left after these industries have been provided for is converted into ammonium sulphate and sold as a fertilizer ingredient. In other words, the ammonia product of the coke ovens seeks the refrigeration rather than the fertilizer market.

In opposition to the slow growth of nitrogen production in the Chilean nitrates and in coke ovens it is significant to note that for the years 1913 to 1920 the production of atmospherically fixed nitrogen enjoyed a growth of approximately 783 per cent. It is also worthy of note that the world took all this nitrogen and asked for more. We may confidently expect the use of nitrogen in fertilizers, in ammunition, and in industry to constantly expand. This expansion will be measured largely by the price of the nitrogen sold. If it can be manufactured and placed on the markets cheaply, and cease to be—as it now is—the determining factor in the price of all mixed fertilizers, we may look forward to a multiplied use of nitrogen. Farmers know that their operations are rapidly depleting our soil of nitrogen, and they willingly would replace this ingredient in the soil if it could be had reasonably. A reasonable estimate of the annual nitrogenous loss from our soils will be between 3 and 4 million tons, to balance which we had in 1920 a total

world's production of nitrogen of only 1½ million tons, not all of which was available for us, of course. To feed the world and to make at least a temporary profit in farming, we must continue to mine our soils until we can mine the air and take from it cheap nitrogen.

In view of the probable insufficient supplies of nitrogen from Chile and from the by-product coke ovens, it is somewhat alarming to know that our consumption of nitrogen is doubling every decade. Whether this increase can be maintained—and it can be accelerated under the most favorable conditions for producing and marketing cheap nitrogen—depends almost wholly upon the development of the air-fixation industry.

Comment by the Committee

By way of suggesting conclusions, your Committee calls attention to these pertinent facts:

(a) That the world is running behind in the production of nitrogen.

(b) That the price of Chilean nitrate is increasing as its supply becomes more inadequate.

(c) That the United States alone paid in 1919, $85,000,000 for Chilean nitrate.

(d) That the United States has paid, including 1919, altogether for Chilean nitrate, plus freight, insurance, etc., approximately $800,000,000.

(e) That this vast expenditure justifies us in seeking other sources of nitrogen.

(f) That nitrogen either by itself or in mixed fertilizers should be placed on the market at a valuation which is not so nearly prohibitory of its use.

(g) That to secure a lessened valuation in nitrogen it must be taken from the air where it is inexhaustible.

(h) That since only about 55 per cent of our estimated total consumption would be produced by our own nitrogen plants of all descriptions, including Nitrate Plant No. 2, there is only a remote possibility of over-production, for the present decade.

(i) That the by-product coke ovens are not to be considered as primarily producers of fertilizer ingredients, because, first, their production depends upon the steel industry; and secondly, their products are sold as much as possible in the form of aqua-ammonia, and the remainder, only, as ammonium sulphate.

V. COSTS AND ESTIMATES

a. Nitrate Plant No. 1

Three large buildings	$ 7,195,496.71
Thirteen smaller buildings	2,270,413.97
Railways, land, walks, village, etc	3,788,661.05
Total	$13,254,571.73

b. Nitrate Plant No. 2

Approximate total expenditures			$69,026,833.43
Overhead, Air Nitrates Corporation		$ 3,504,628.14	
Construction Fees, Air Nitrates Corp., including unpaid balance		1,500,000.00	
Temporary Buildings		4,260,550.00	
Chemical Plant		37,842,899.98	
Power Plant		10,436,337.05	
Land for Plant Reservation Site		237,711.00	
Permanent Housing		2,767,837.36	
Reservation Site and Public Works		1,427,162.47	
Community and Commissary Activities	$9,411,528.79		
Less Cash Revenues (Miscellaneous and Commissary)	4,922,779.69	4,488,749.10	
Quarry		715,494.65	
Operation		1,860,463.60	
TOTAL			$69,026,833.43
Less Operating Expenditure			$ 1,860,463.60
Construction Expenditure			$67,166,369.83

c. The Wilson Dam

Various estimates have been offered as to the total cost of this dam, but as conditions relative to cost are changing so rapidly it is impossible to secure great accuracy. Two estimates are herewith submitted. The first one is based on conditions as they were in 1919 and is being held on that level in order to be definitely sure that the final cost cannot exceed the figures given. The second estimate is based on conditions as they were in 1916 but there has been added in each item a 100% increase in the hope that such an arbitrary increase will approximately represent the difference in the cost factors in the year 1916 and at the present time.

(A)

Allotted for construction as per National Defense Act of 1916		$13,160,000.00
Transferred from Armament and Fortification Fund, June, 1920		4,000,000.00
Total Allotments to Date		$17,160,000.00
Total approximate expenditures and commitments to date		16,650,000.00
Amount to be asked from Congress		10,000,000.00
Approximate total cost (based on 1919 conditions)	$50,000,000.00	
Amount properly allotted to navigation purposes	4,500,000.00	
Net cost for power purposes		45,500,000.00
Production cost, one horse-power per year (based on average H. P. 300,000, and a 10% interest and operating expense)		15.00

(B)

General engineering and office expenses	$ 2,275,000.00
Camps, general plant, railroad constructions	2,212,000.00
The dam proper	4,127,000.00
Locks	1,064,000.00
Substructure of powerhouse and tailrace	2,000,000.00
Flowage damages	350,000.00
Road changes	30,000.00
Clearing	76,000.00
Head gates	135,000.00
Racks	68,000.00
Cranes	50,000.00
Generating equipment	4,200,000.00
Cables and wiring	150,000.00
Total	$16,737,000.00
100% increase	16,737,000.00
Total cost of Dam	$33,474,000.00
Amount properly allotted to navigation purposes and not useful for power	$ 4,500,000.00
Cost of dam for power purposes	$28,974,000.00
Production cost of one horse-power per year (based on average H. P. 300,000, and a 10% interest and operating expense)	9.66

Note: One horse-power at Niagara Falls sells at $17.00 per year.

d. Manufacturing Cost of Calcium Cyanamid (Lime-Nitrogen) at United States Nitrate Plant No. 2.

(Based on a two-weeks' run with steam power)

Item	Two weeks' test at approximately 20% capacity, production 1450 tons; cost per ton of lime-nitrogen. Quantity Per Ton Lime-Nitrogen	Unit Cost	Cost Per Ton of Lime-Nitrogen	Estimated cost of manufacture at 100% capacity, production 222,200 tons per year. Quantity Per Year	Unit Cost	Total Yearly Cost	Cost Per Ton of Lime-Nitrogen
Limestone, tons	2	$2.25	$4.50	388,900	$1.25	$486,000	$2.19
Coke, tons	0.54	9.75	5.26	120,000	6.00	720,000	3.24
Coal, tons	0.26	4.25	1.10	46,700	4.00	187,000	.84
Electrodes, lbs.	44	.06	2.64	8,400,000	0.05	420,000	1.89
Power, K.W. hrs.	2,765	.00738	20.40	624,000,000	0.0042	2,496,000	*11.23
Miscellaneous material & supplies			2.75			591,000	2.66
Labor			11.35			1,600,000	7.20
Total			$48.00			$6,500,000	$29.25
Overhead			13.85			411,000	1.85
Total			$61.85			$6,911,000	$31.10
Royalties per present contract			2.56			1,533,000	6.90
Operating fee per present contract			3.12			....	......
Total			$67.53			$8,444,000	$38.00

One ton of lime nitrogen when oiled and hydrated produces 1.10 tons of commercial cyanamid.

Cost of one ton commercial cyanamid ($38.00 divided by 1.10)	$34.55
Cost of oil and oiling	.75
Bagging	1.75
Research and main office	2.10
Total, Commercial Cyanamid	$39.15

*Note: When the Wilson Dam is complete, the cheaper water power will be available. If we assume this to cost $0.00075 per K.W. hour, the cost of Cyanamid fertilizer will be reduced to **$30.85** per ton. It should be noted that the power cost of $0.00075 per K.W. hour, used in this and the following tables is not as large as will be placed upon the power which is sold, but represents approximately what may fairly be charged against the nitrate plants for power.

e. Manufacturing Cost of Ammonium Nitrate at United States Nitrate Plant No. 2.

(Based on a two-weeks' run with steam power)

	Two weeks' test at approximately 20% capacity, production 950 tons; cost per ton of nitrate.			Estimated cost of manufacture with Lime Nitrogen Plant running 100% capacity; 20% of the product being converted into 22,000 tons of nitrate.			
Item	Quantity Per Ton Ammonium Nitrate	Unit Cost	Cost Per Ton of Ammonium Nitrate	Quantity Per Year	Unit Cost	Total Yearly Cost	Cost Per Ton of Nitrate
Limestone, tons	4.04	$2.25	$9.08	77,780	$1.25	$97,200	$4.42
Coke, tons	1.09	9.75	10.62	24,000	6.00	144,000	6.54
Coal, tons	.53	4.25	2.22	9,340	4.00	37,360	1.70
Electrodes, lbs.	.89	0.06	5.34	1,680,000	0.05	84,000	3.82
Power, K.W. hrs.	5,945	.00738	43.87	133,270,000	0.004	533,080	24.22
Miscellaneous material & supplies			11.36			266,000	12.08
Labor			34.73			509,000	23.14
Total			$117.22			$1,670,640	$75.92
Overhead			40.38			100,000	4.56
Total			$157.60			$1,770,640	80.48
Royalties per present contract			6.27			254,000	11.55
Operating fee			5.00			....	.....
Total			$168.87			$2,024,640	$92.03
Bagging							2.00
Research and Main Office							5.63
Total							$99.66

Note: When the Wilson Dam is complete, the cheaper water power will be available. If we assume this to cost $0.00075 per K.W. hour, the cost of nitrate will be reduced to **$80.05** per ton.

f. Manufacturing Cost of Ammonium Sulphate at United States Nitrate Plant No. 2

(Based on a two-weeks' run with steam power)

Estimated cost of manufacture with lime nitrogen plant running 100% capacity; 40% of the product being converted into 86,000 tons of sulphate.

Item	Quantity Per Year	Unit Cost	Total Yearly Cost	Cost Per Ton of Sulphate
Limestone, tons	155,560	$ 1.25	$ 194,450	$ 2.27
Coke, tons	48,000	2.00	288,000	3.35
Coal, tons	18,680	4.00	74,720	.87
Electrodes, lbs.	3,360,000	0.05	168,000	1.96
Power, K.W. hr..............	255,482,400	0.004	1,022,000	11.89
Sulphuric Acid	82,600	10.00	826,000	9.60
Miscel. materials and supplies.			447,500	5.20
Labor			1,033,000	12.01
Total			$4,053,670	$47.15
Overhead			198,000	2.30
Total			$4,251,670	$49.45
Royalties per present contract			582,000	6.77
Total for 86,000 tons of ammonium sulphate........			$4,833,670	$56.22
Assuming 65% would be shipped in bulk, the cost of bagging the remainder pro-rated is estimated at........................				.50
Research and Main Office..................................				3.41
Total				$60.13

Note: When the Wilson Dam is complete, the cheaper water power will be available. If we assume this to cost $0.00075 per K.W. hour, the cost of sulphate will be reduced to **$50.58** per ton.

g. Estimated cost (exclusive of interest charges) of producing phosphoric acid by the electric furnace method, assuming power at $25.00 per H. P. year.

Items	Quantity (tons) "Mine Run"	Cost of Material Per Ton Tenn.	Cost Per Ton of Acid (P2O5) Raw Rock	Quantity (tons) "Washed"	Cost of Material Per Ton Tenn.	Cost Per Ton of Acid (P2O5) Raw Rock
Phosphate Rock		$	$	3.32	$7.00	$22.24
Phosphate Matrix	3.73	1.50	5.40			
Sand	1.50	.50	.75	1.50	.50	.75
Coke	.75	4.50	3.37	.75	4.50	3.37
Operating Expenses— Electrodes, $2.13; Labor, $4.45; Power, $44.01...			50.59			50.59
Total Cost Per Ton......			$60.11			$76.95
Total Cost Per Pound...			.03+			.04—

Note: When we assume power to cost $0.00075 per K.W. hour ($0.0005625 per H.P. hour) and use this cheaper hydro-electric power, the power item will stand at $4.92 per H.P. year instead of at $25.00 as is used in the above table which is approximately the commercial rate for power. This will reduce the operating expense for power as estimated above from $44.01 to $8.66 and give a total cost per ton for "Mine Run" of $35.35 and for "Washed" of $41.60; or, per pound of .01767 and .0208, respectively.

The estimates in the table given above are all based on a ton production of P2O5. To transfer these estimates into terms of 16 per cent acid phosphate it is necessary to remember that there are only 320 pounds of P2O5 in a ton of acid phosphate. By taking the pound costs in the table and multiplying them by 320 we ascertain the cost of 16 per cent acid phosphate, which will give us for the "Mine Run" $9.60 and for the "Washed" $12.80. With power from the hydro-electric installation, these prices further reduce to $5.65 and $6.65, respectively, per ton, of acid phosphate.

The figures in the above table and notes constitute what will doubtless be a very spectacular development relative to fertilizer prices.

h. Estimated supply and consumption of Nitrogen for 1924 and 1930, in tons of pure nitrogen.

	—Nitrogen—	
	Tons	Tons
Estimated Peace Time Consumption in—	1924	1930
Agriculture	172,000	285,000
Industries	120,000	150,000
Military explosives	2,500	3,000
Total Consumption	294,500	438,000
Estimated Domestic Supply from—		
By-product coke ovens	122,500	159,500
Privately owned fixed nitrogen plants	....	25,000
Total Domestic Supply	122,500	184,500
Deficiency in domestic supply if Government plants do not operate	172,000	353,500
Estimated supply from Government fixed nitrogen plants	45,000	55,000
Deficiency in domestic supply if Government plants operate	127,000	198,500
Estimated Imports Necessary—		
Canadian lime-nitrogen	15,000	15,000
Chilean or European nitrate, if Government plants not operated	157,000	238,000
Chilean or European nitrate, if Government plants operated	112,000	183,500
Proportion of Total Consumption Furnished by Domestic Supply—		
If Government plants not operated	41.6%	42.2%
If Government plants operated	56.9%	54.7%

I. Nitrogen in Red Clover and Cow-peas.

1	2	3	4	5	6	7	
		—Nitrogen in Pounds Per Acre—			Fixed in Soil		
Crop	Condition of Crop	Whole Plant	From Air	Roots and Stubble	Per Acre	References	
Red Clover	mature	103.00	68.60	33.20	*1.20	Delaware	A. E. S.
Red Clover	mature	103.40	68.90	40.30	†5.80	New York	A. E. S.
Mammoth Clover	mature	146.00	97.30	78.40	†29.70	New York	A. E. S.
Cow-pea	mature	69.70	46.40	25.30	†2.00	Mississippi	U. S. D. A.
Cow-pea	mature	112.90	75.20	16.70	*21.00	Indiana	A. E. S.
Totals		535.00	356.40	193.90	†15.30		

NOTES

1. The sum of 4 and 5 when compared to 3 gives the amount of nitrogen fixed in the soil, or taken from the soil in growing the plant.

2. In 6 the sign (*) means the pounds of nitrogen fixed in the soil and (†) means what has been taken from the soil.

3. It seems that not all clover and-cow-pea fields enrich the soil by chemical action.

4. No figures are available in this connection relative to alfalfa.

5. The average yield per acre of alfalfa hay in the United States for 1920 was 2.74 tons. This hay analyzes 2.3% of nitrogen, which gives us .063 tons of nitrogen, or 126 pounds in each ton of alfalfa hay. How much of this is drawn from the air and how much from the soil has not yet been definitely determined.

6. The average yield per acre of red clover hay in the United States for 1920 was 1.46 tons. This hay analyzes 2% of nitrogen, which gives us .029 tons of nitrogen, or 58 pounds, in each ton of red clover hay. It would seem, from the above table, that many red clover fields are drawing upon the nitrogen reserves of the soil instead of adding thereto.

j. Water Power at Muscle Shoals.

(Based on Flowage Records of 19 Years)

Horse-power in Stream	Months Avail-able	—Horse-power Used and Wasted With— 4-Power Units Used	Wasted	10 Power Units Used	Wasted	18 Power Units Used	Wasted
100,000	12	100,000	....	100,000	....	100,000	0
240,000	9	120,000	120,000	240,000	....	240,000	0
360,000	7	120,000	240,000	336,000	24,000	360,000	0
480,000	5½	120,000	360,000	336,000	144,000	480,000	0
600,000	4	120,000	480,000	336,000	264,000	600,000	0

Note: The first four units are to be of 30,000 H. P., but all others are to be rated at 36,000 H. P.

k. Royalties.

Product	—Royalty to— Air Reduction Company	American Cyanamid Company	Total Per Ton
Commercial lime-nitrogegn	$0.522	$ 5.753	$ 6.275
Ammonium nitrate	1.16	10.395	11.555
Ammonium sulphate	.594	6.176	6.770

Note: Although most of the patent rights on methods and devices for fixing atmospheric nitrogen are owned by the American Cyanamid Company, some are owned by the Air Reduction Company. This makes it necessary to pay two royalties. These royalties are now subject to arbitration, however.

l. Maintenance or Stand-by Expense of Nitrate Plants Nos. 1 and 2.

	1920 July 1, 1919 to June 30, 1920	1921 July 1, 1920 to June 30, 1921	*1922 July 1, 1921 to June 30, 1922
Nitrate Plant No. 1	$171,605.58	$ 80,500.00	$ 60,000.00
Nitrate Plant No. 2	472,642.63	179,476.20	132,000.00

It has been stated by War Department officers that the daily operation of these plants is equivalent to a storage of 150,000 tons of nitrate of soda for explosives. At $50 per ton this represents an investment on the part of the Government of $7,500,000 which, at 5% interest annually, amounts to........$375,000.00

Storage on 150,000 tons annually............................. 100,000.00
(Estimated by War Department officials at $129,000)

Total for 1922* $667,000.00

* Estimated

m. World's Production of Fixed Inorganic Nitrogen.

(In metric tons of nitrogen)

Product	1913	1917	1920	Per Cent of Increase from 1913-1917
Chilean Nitrate	390,000	392,000	500,000	28.
By-product from coke ovens	343,000	364,000	410,000	19.
Atmospheric Nitrogen (Arc, Haber, Cyanamid)	85,000	340,000	665,000	783.

n. Comparative Prices

(In tons)

Products	Muscle Shoals Steam Power	Muscle Shoals Water Power	Wholesale 1920 Prices Imports	Wholesale 1920 Prices Domestic
Lime-nitrogen (21%)..........	$39.15	$30.85	$65.36	....
Ammonium Nitrate (35%).....	99.66	80.05	*	....
Ammonium Sulphate (21%)...	60.13	50.58	132.67	$110.00
Acid Phosphate (16%)........	.....	......	......	19.50
From "Mine Run"	9.60	5.65	......	....
From "Washed"	12.80	6.65	......	....
Nitrate of Soda (Chilean Nitrate, 17%)	.....	......	68.50	....

Note: All wholesale prices here quoted are taken from the 1920 Year Book of the "Oil, Paint and Drug Reporter."

* Not quoted as fertilizer.

VI. THE REPORT OF THE NITROGEN PRODUCTS COMMITTEE OF THE MINISTRY OF MUNITIONS OF WAR OF THE BRITISH GOVERNMENT

The greatest contribution to the literature relating to the fixation of atmospheric nitrogen that is now available is the report of the Committee of eminent Englishmen, twenty-four in number, who were appointed in June, 1916, to investigate fully all the scientific and industrial problems incident to the creation of a nitrogen fixing industry in the Empire. This report contains 360 large pages, and is the result of months of painstaking work on the part of the Committee. The final report of this Committee was made in May, 1919.

It will be of decided value in our study of the Muscle Shoals project to know what conclusions were reached by the Nitrogen Products Committee. Consequently, space in this report is being taken for several quotations from the English document.

(A) "A large addition to the home output of ammonium sulphate coupled with the increasing competition of synthetic nitrogen products would undoubtedly cause a reduction in its market price, and this would be of advantage to agriculture and to the export trade."

(B) "It appears probable that undertakings of this character would have to receive the support of the Government or be carried out entirely as national projects."

(C) "The main characteristics of the cyanamid process are:

(a) The relatively small power requirements per unit fixed as contrasted to the arc process.

(b) The direct production of a solid nitrogenous fertilizer (lime-nitrogen), thus avoiding the costs incurred in all the other established synthetic processes for converting liquid products into a solid marketable form.

(c) The production of a cheaper MARKETABLE form of combined nitrogen than is obtainable by any other fixation process.

(d) Its great adaptability as regards the products obtainable.

(D) "There seems no reason why manufacture both of carbide and also of calcium cyanamid (lime-nitrogen), if laid out on a large scale, should not be successful in this country. There are blocks of undeveloped water power in Scotland of sufficient size for the operation of a large factory."

(E) "The market price of a metric ton of **combined** nitrogen in the United Kingdom prior to the war varied from 66 pounds to 67 pounds (in the form of ammonium sulphate and Chile nitrate respectively).

(F) "The synthetic processes can produce a metric ton of combined nitrogen at a cost, at the factory of from 20 pounds to 30 pounds.

(G) "The synthetic processes can produce a metric ton of **concentrated** (93 to 96 per cent) nitric acid for about half the cost of the Chile nitrate retort process."

(H) "The synthetic processes can produce a metric ton of combined nitrogen ready for the fertilizer market, as cyanamid or ammonium sulphate, at a cost, at the factory, of about or even less than one-half the **pre-war market price** of combined nitrogen in the United Kingdom."

(I) "A large proportion of the synthetic plant would find an application under peace conditions for the manufacture of nitrogenous fertilizers, either for home consumption or for exportation."

(J) "As compared with the retort process (used in connection with the Chile nitrate) the saving in the running costs over a period of two years would probably cover the initial capital outlay."

(K) "Dealing broadly with the post-war demand, the requirements of agriculture are certain to be much larger than formerly, the imperative need for maintaining and extending the world's production of food, and the vital importance of combined nitrogen for this purpose, having emerged as the salient lessons of the later stages of the war."

(L) "The consumption of combined nitrogen practically doubled in the ten years before the war. When account is taken of the relative areas under cultivation in the food producing countries of the world, of the pre-war consumption of nitrogenous fertilizers in the most progressive of the agricultural countries, and of the corresponding consumption in the remaining countries, it is abundantly clear that the quantities of nitrogenous manures employed were in many cases below the most advantageous or profitable level. The difficulties experienced during the war period in obtaining supplies have already provided a salutary lesson as to the importance of fertilization, and the resulting wider recognition of the value of fertilizers will lead to an increase in the demand for nitrogenous manures in countries where the consumption has hitherto been very small in proportion to the area under cultivation. In the opinion of the Committee, the provision of a really cheap supply of fixed nitrogen would lead to a greatly extended consumption of nitrogenous fertilizer."

(M) "There will be also an increased industrial demand for fixed nitrogen. Nevertheless, the total requirements for industry are unlikely to amount to more than a relatively small proportion of the demand for agriculture."

(N) "It is evident—that the supremacy of the Chile nitrate industry is already being challenged, and the near future holds out the prospect that ammonium sulphate of synthetic nitrogen products may become the dominant factor in the nitrogen market and govern the price of nitrate instead of following it as hitherto."

(O) "The proved utility of Chile nitrate as a fertilizer, however, is such as to insure its position in agriculture for a long time to come, but the extent of the demand under post-war conditions will be largely determined by the price at which the product can be marketed."

(P) "Other things being equal, however, the preponderating factor in determining the future consumption of combined nitrogen in agriculture will be the price at which it is procurable. The possibilities in this direction due to the development of the synthetic nitrogen industry have already been indicated, and in the event of adequate supplies of fixed nitrogen being forthcoming at a price showing even a moderate reduction upon the pre-war figure, the Committee is strongly of the opinion that there will be a very substantial increase in the consumption. If, however, the price of nitrogen remains at the level of the present controlled price of ammonium sulphate, the demand is likely to be largely determined by factors such as the prices obtainable for agriculture produce."

(Q) "The Committee is satisfied that synthetic processes can at the present time be operated in the United Kingdom upon a sound economic basis and that the undoubted advantages enjoyed by such methods will become more pronounced in the course of time as the result of constant efforts towards improvement."

(R) "The Committee is emphatically of the opinion that the national interests demand the establishment forthwith of nitrogen fixation and allied processes upon a considerable manufacturing scale."

(S) "It appears that the question of over production which was raised in evidence given before the Committee, is hardly likely to constitute a serious factor in the post-war situation."

(T) "A minimum of perhaps 70 per cent of the world's total supplies of nitrate and ammonia nitrogen was utilized in agriculture prior to the war."

(U) "Combined nitrogen (as cyanamid or ammonium sulphate) can be obtained by synthetic processes at a cost, at the factory, which is less than half the market price of combined nitrogen from other sources, pre-war conditions being taken as the basis in each case."

(V) "The world's demand for combined nitrogen appears to double every ten years. The increased production during the war has not been more than the normal rate of increase during peace."

(W) "As far as the United Kingdom is concerned, nitrogen fixation and allied processes will constitute a new 'key' industry. The Committee is of the opinion that the initiation and development of the industry will require the active support of the Government."

Comment by the Committee.

1. As an aid in the study of the foregoing quotations, it may be well at this point to explain that there are three processes which are used commercially in the fixation of atmospheric nitrogen. Whether or not one or another of these processes enjoys any particular advantages over the others depends altogether upon several factors that enter into the manufacturing of fixed nitrogen. From a practical and agricultural point of view the cost of the operation, and the consequent market price of the commodity, is always the determining factor, so far as the availability for farming uses is concerned. Then again, the power required necessarily enters into the consideration. That process which requires least power, other things being equal, will naturally be the most favored method of fixing nitrogen. Also the proximity of the plant to its sources of raw material, and their availability, will assuredly reflect themselves in the ultimate price.

The three processes referred to frequently by the Nitrogen Products Committee are the arc, the Häber (pronounced Haber), and the cyanamid or lime-nitrogen.

The arc process enjoys the distinction of being simple in that it uses the electric arc to force a combination of nitrogen and oxygen, which combination is caught in water, and after treatment in an alkali produces, as a primary product, nitric acid. Air and water constitute the main raw materials in this process. The handicap of the arc process is that it requires such an expenditure of electrical power. Not more than 4% of the electrical energy used is represented in the nitrogen secured. This makes the arc process almost indefensible except where water power to generate the electrical energy is super-abundant. Norway is the only country to use this process commercially, which may be accounted for by a study of her immense water power resources.

The Haber process is used mainly in Germany and was her principal reliance for nitrogen during the war. This process is based on securing a highly precise mixture of hydrogen and nitrogen, under great pressure and while subjected to terrific heat. If the mixture of these gases is properly maintained the heat and the pressure are easily controlled and the resulting product of fixed nitrogen is secured. But, however, if too much of one gas is admitted or too little of the other, the chemical reaction is highly dangerous in that an explosion occurs. A war incident may be cited in which the American war planes were bombing a German plant of the Haber variety, and although none of the bombs hit the mark the plant was destroyed on account of the workmen fleeing for safety from the bombs and so leaving the gases uncontrolled for half an hour. The principal advantage of this process over any

other known process is the small amount of electrical energy required. Approximately only one-fourth the energy is used in this process that is consumed in the lime-nitrogen method, and only about one-sixteenth as much as the arc process demands. Nitrate Plant No. 1 was built to use the Haber process but has never produced fixed nitrogen commercially. The Committee desires to suggest, though, that if the Germans can do it, so can we; and to suggest further that the difficulties encountered in the successful application of the well-known chemical laws concerned in this process, are mostly of a mechanical nature, now, and we may confidently expect such difficulties to be overcome by the ingenuity of our chemists and mechanics working together.

The cyanamid or lime-nitrogen process has been explained at some length in a preceding division of this report. Suffice it to say that this process, all things considered, is meeting with the most favor all over the world, and is the one used in Nitrate Plant No. 2.

2. The Report of the Nitrogen Products Committee of the British Government accentuates the following conclusions which have been arrived at in this country relative to a development of the nitrogen-fixing industry:

(a) That such an industry would have the effect of reducing prices on the nitrogen content of fertilizers.

(b) That such an industry would have the controlling influence in the determination of market quotations on fertilizers.

(c) That such an industry should receive the support of the Government.

(d) That such an industry, at least with our present knowledge of other processes, should be based on the cyanamid, or lime-nitrogen process.

(e) That the synthetic processes (arc, Haber, cyanamid) may reasonably be expected to produce combined nitrogen at approximately one-half the pre-war price.

(f) That the establishment of such an industry, although expensive, might be expected to amortize the original capital cost in a few years by the saving effected in market prices on nitrogen.

(g) That agriculture will use nitrogenous fertilizers in proportions which increase or decrease as the price of nitrogen fluctuates.

(h) That agriculture is the biggest user of nitrogen and therefore is primarily concerned in its production at a price which will permit of its use.

(i) That the Chilean nitrate industry will continue as a factor in the fertilizer market indefinitely, but that we should place ourselves in position to be independent of foreign supplies, both in times of peace and war.

(j) That a plant to manufacture fixed nitrogen can be operated on an economically sound basis.

(k) That the nitrogen industry is not of concern only to one group—as the military, the industrial, the agricultural—nor is it of interest to merely one section of our country. But it is a national problem which challenges the interest of all citizens who have regard for public safety in time of war or who desire that soil conservation and food production be safeguarded in order that agriculture and industry may prosper.

(l) That there is slight danger of an over-production of nitrogen so long as the price factor is held constant and equable.

VII. POWER

Enough information has been offered in other portions of this report to show that any plant designed for the fixation of atmospheric nitrogen, which is to be placed on the competitive markets, must have readily and steadily available the cheapest form of power. In war times when low cost of operation was not of prime importance, provided a higher cost expedited our activities, it was possible to contemplate the operation of such plants as Nitrate Plant No. 2 with power which did not qualify as being the least costly. Accordingly a giant steam plant was installed to run the plant during the interim between the completion of No. 2 and of the Wilson Dam—it being known that the power from the dam could not be available for perhaps three years after the plant began production. Nitrogen production by steam power is, of course, more costly than by water power, which is true of any other industry that can be hydro-electrified.

In peace times the successful and economical operation of Nitrate Plant No. 2 for the production of fertilizers depends almost wholly upon the completion of the hydro-electric plant in connection with the Wilson Dam. The whole proposition at Muscle Shoals revolves around the item of cheap power. Without this cheap power it is hardly possible to hope that the production of nitrogen will be secured at a figure low enough to materially affect the market price of fertilizers. All estimates, data, and reports from every country point significantly to hydro-electric power as being the determining factor in the manufacturing of atmospheric nitrogen. All other competitive factors, such as the supply of raw materials; their location with regard to the plant; the available market for the product; the chemical and mechanical difficulties; all take places of secondary importance when compared with the one indispensable factor, cheap power.

That there will be an abundance of water power at Muscle Shoals upon the completion of the Wilson Dam is evident when the salient facts connected therewith are considered. The dam, being 100 feet high, will maintain a normal head of 95 feet. The dam and powerhouse are being constructed for the ultimate installation of 18 generating units, each consisting of a water turbine and generator capable of producing 30,000 or 36,000 horsepower. Seventeen of these units are expected to be ready for operation at all times, leaving one out for repairs. These 17 operating units will, therefore, have a total normal output of about 600,000 horsepower. The installation plans call for the immediate placing of only four of these units, which will be ample to operate Nitrate Plant No. 2, as they will produce 120,000 horsepower. It is worthy of note that the installation of only four units will allow much water to flow over the top of the dam unused during most of the year, whereas if 10 units were installed they could operate to full capacity on an average of half the time, which would justify their installation.

These statements are based on the known flow of the Tennessee River at Muscle Shoals during the period from 1895 to 1914 inclu-

sive, with only one year not considered on account of incompleteness in the records. In all that time, 19 years, the lowest the river ever dropped would have produced 85,000 horsepower; but only 6 years of the 19 recorded show a flow at any time so small as to drop below the 108,000 horsepower required to operate Nitrate Plant No. 2. In these six years the time in which the flow was less than sufficient to produce this required horsepower amounted to 1.3 per cent of the total time. In these times of low flow the steam plant stands ready as auxiliary power, but to keep the power constant for the four units required to operate No. 2 the steam plant would have to be fired up only one day out of sixty, on an average.

The records of flowage at Muscle Shoals show that for nine months in the year there will be approximately 240,000 horsepower, for 7 months in the year 360,000 horsepower, for 5½ months in the year, 480,000 horsepower, and for 4 months in the year 600,000 horsepower, making an average of 300,000 horsepower for the whole year.

If we decide to install only the first four power units and be satisfied to make no use of the remaining power we must be content to see much water spill over the dam. If, however, we desire to harness the full force of the stream we will advocate the placing of the entire battery of 18 horsepower units even if it can not be used thoughout all the year. These considerations have given rise to descriptive terms to define the amounts of power available at Muscle Shoals. All that power (approximately 100,000 H. P.) which can be depended upon from day to day, year in and out, as the average lowest power available, is known as primary horsepower. If for one day, or even for one week, as an extraordinary occurrence, the river should drop below this average lowest power line no recognition is given such occurrence in this definition. All other waterpower at Muscle Shoals, from the minimum of 100,000 H.P. to a maximum of 600,000 H.P., is called secondary power.

As a maximum waterpower development at Muscle Shoals with 18 power units installed we have: 100,000 primary horsepower plus 500,000 secondary horsepower. It needs to be remembered that the primary power does not vary—it is constant—but the secondary power is quite variable.

There is a third power available at Muscle Shoals from the steam plant. This classifies neither as primary nor secondary power but should be considered altogether as auxiliary power. Its use should be to supplement the secondary power as occasion requires.

The immense reserves of secondary power available at Muscle Shoals, not to mention the primary power which is just about ample to operate No. 2 constantly, brings to our attention the necessity of finding a suitable market for such excess power. It may not reasonably be expected that such a market will develop instantly. The history of great hydro-electric plants has been that at first there has been an excess of power for the available market; but that soon the demand for power exceeded the capacity of the plants. So it will undoubtedly be at Muscle Shoals. It would be foolhardy in

the extreme, no doubt, to expect at once handsome dividends on our governmental investment at Muscle Shoals other than that which comes to all citizens from a satisfactory supply of nitrogenous products.

It would be unfair though, to estimate the cost per horsepower of the Wilson Dam on any other basis other than one that contemplates the eventual use of all power classified above. Undoubtedly, either by direct location of factories or by transmission, all the power that the dam is capable of producing will be utilized. Therefore, taking the total estimated cost of the dam with its power equipment but without the navigation features (which will be found in detail in another division of this report) and dividing by the maximum power developed we have the following: $45,500,000 divided by 600,000 equals $75, cost of installing each horsepower if all power were used constantly.

Inasmuch, however, as the primary and secondary power do not stand at that high figure all the time, but maintain a mean average of about 300,000 horsepower, the following equation more nearly represents a fair estimate of installation costs per horsepower. $45,500,000 divided by 300,000 equals $150, cost of installing each horsepower, based on average power developed. It will be seen that the initial capital cost of one horsepower at Muscle Shoals compares favorably with the same power when bought in the form of a high grade gasoline engine for use about the barn or in the shop. It is only fair to state, however, that other estimates as to the cost of the dam, exclusive of navigation features, and which are from dependable sources, reduce the figures above used by fully $15,000,000. The estimate here used was made in 1919 at peak prices and is being adhered to as the highest possible cost of the dam.

Moreover, the cost of operation, per horsepower, after the installation is paid for is far less than that of any other kind of plant, not excepting the most economical steam plant. In this connection the great saving in coal that would be brought about should not be overlooked.

Comment by the Committee

Recognizing that the power development at Muscle Shoals as represented by the Wilson Dam equals in importance, though not in expense, the building of Nitrate Plant No. 2; and fully realizing that No. 2 will be greatly handicapped until the dam is completed; and considering that the dam will meet its first justification for the expense of building it in the operation of No. 2; your Committee, therefore, desires most candidly to state its thoughts on the correlation that exists between the two undertakings:

(a) First of all, it is desirable that the Muscle Shoals project pay a reasonable return on a reasonable capitalization.

(b) Next in importance, no doubt, is the necessity for operating No. 2 by power from the Wilson Dam.

(c) Provision should be made for installing, at least the major part, of the power units so that excess power would be available.

(d) If the complete installation of power units is placed then it might be well to suggest that the excess power be disposed of commercially but that in any event the necessities of the nitrate plants for power be met fully before such excess power is sold.

(e) There will be enough excess power, however, to return a handsome revenue to the government.

(f) It must not be forgotten that the combined expenditures at Muscle Shoals in the Wilson Dam and Nitrate Plant No. 2 represent a citizens' investment made for us by our government. This investment will be of value to all citizens, and consequently, all citizens should desire that the entire project be put on a business basis. The effort should be to make this gigantic undertaking of our government "pay out." It can only be done by a business-like administration of its affairs as will be explained in a later division of this report.

VIII. POSSIBILITIES

In our consideration of Nitrate Plant No. 2 thus far in this report attention has been focused almost exclusively upon its capacity to produce nitrogenous fertilizers, as lime-nitrogen, ammonium nitrate, and ammonium sulphate. In fact the plant was built as a nitrogen-fixation establishment so that nitric acid and nitrates could be available for the manufacture of military explosives and for use in fertilizers. That in the erection of this great plant Congress had in mind its dual purpose—military and agricultural—is shown by the following quotation from Section 124 of H. R. 12766 of the 64th Congress:

> "The President of the United States is hereby authorized and empowered to make, or cause to be made, such investigation as in his judgment is necessary to determine the best, cheapest, and most available means for the production of nitrates and other products for munitions of war and useful in the manufacture of fertilizers and other useful products by water power or any other power as is in his judgment the best and cheapest to use; and is also hereby authorized and empowered to designate for the exclusive use of the United States, if in his judgment such means is best and cheapest, such site or sites, upon any navigable or non-navigable river or rivers or upon the public lands, as in his opinion will be necessary for carrying out the purposes of this Act; and is further authorized to construct, maintain, and operate, at or on any site or sites so designated, dams, locks, improvements to navigation, power houses, and other plants and equipment or other means than water power as in his judgment is the best and cheapest, necessary or convenient for the generation of electrical or other power and for the production of nitrates or other products needed for munitions of war and useful in the manufacture of fertilizers and other useful products."

(a) Ammonium Phosphate.

A great development that can be hoped for at Nitrate Plant No. 2, is the obtaining of available phosphoric compounds from phosphate rock by treating it in the electrical furnace. It will be remembered that limestone and coke are fused into carbide by means of intense heat in the electric furnaces, and this fusion constitutes the first step in the fixation of atmospheric nitrogen. Later steps produced lime-nitrogen, and from it is produced ammonia gas. A gas is of no value as a fertilizer as it cannot be placed in the soil; it

must be absorbed in some liquid to make it available, and later reduced to a solid form of a crystalline nature. In No. 2 this ammonia gas is absorbed either in nitric acid to produce ammonium nitrate, or in sulphuric acid to produce ammonium sulphate. In fact there are several acids that will absorb this ammonia gas. To cite only one more, it may be stated that hydrochloric acid can be used to form ammonium chloride, which is good for fertilizer use. In Nitrate Plant No. 2, if we desire to go beyond the lime-nitrogen or cyanamid product—which is of itself a good fertilizer but with limitations—and produce the usual fertilizer commodities which are generally used, we have to reduce our lime-nitrogen to a gas, ammonia, and use that as the base of our further developments. This ammonia gas contains practically all the nitrogen that the lime-nitrogen carried, but it, in its turn, has to have its nitrogen fixed or caught as above stated, in liquid form first, through the use of an acid, and then solidified by boiling.

It is, as above set forth, largely immaterial to this ammonia gas which acid is used to absorb or catch it. Heretofore in this report slight consideration has been given any fertilizer question except the purely nitrogenous one. If, however, other acids can be produced in No. 2 which will absorb this ammonia gas, and if these other acids of themselves have fertilizing values, then it will be well to make such slight changes and additions in the equipment as will enable us to produce more than one fertilizer constituent.

By using the same electric furnaces that have been previously described, and by filling them with phosphate rock, coke, and sand, instead of lime-rock and coke, it is possible to produce a very pure form of phosphoric acid which carries 45% of available phosphates. Here again we see the desirability of the location of No. 2 as some of our largest phosphate beds lie in Tennessee not far from Muscle Shoals. This plan has never been tried out in No. 2, and in fact some alterations would need to be made in the equipment; but there has been a six months' test made of this process by the United States Department of Agriculture on a commercial scale. The result of this test, financially, was that on account of high priced electric power, the product of the test cost more than producing acid phosphate by the old and wasteful method of treating the raw phosphate rock to a bath of sulphuric acid. The conclusion, however, seems to be that with hydro-electric power as cheaply as it can be had at Muscle Shoals the process of making phosphoric acid is entirely feasible and practicable.

In the usual way which is now followed in the production of acid phosphate great use is made of sulphuric acid which has no fertilizing value whatever but really has an acidulous effect of the soil. This is also true of the use of sulphuric acid in No. 2 as an absorbent for the ammonia gas to make ammonium sulphate. In both instances we are carrying something along, sulphuric acid, which has no fertilizing value.

A substitution of phosphoric acid, which carries a very necessary fertilizer ingredient, for the other acids above mentioned, as the absorbent for the ammonia gas, would result in giving us ammonium

phosphate, a fertilizer carrying two very valuable soil foods—nitrogen and phosphate. This ammonium phosphate differs from the ammonium nitrate and ammonium sulphate previously described as products of No. 2, in that it carries two fertilizers in one compound instead of one fertilizer in two compounds.

(b) Potassium Phosphate.

It will be seen from the foregoing paragraphs that at Muscle Shoals we have assuredly a plant to produce nitrogen, and also we have the same plant available as a possible producer of phosphate. This gives us two of the three ingredients that usually go to make up the mixed fertilizers which are sold today.

In close proximity to the plant at Muscle Shoals there lie great beds of potash shales many of which contain 4% of potash. It has been experimentally ascertained that the substitution of these potash shales for the sand which is used in the production of phosphoric acid in the electric furnaces does not materially interfere with the chemical reaction that produces phosphoric acid, but does produce at the same time a fusion or union of the potash in the shale with the phosphoric acid. This gives us potassium phosphate with phosphoric acid carrying the potash.

The production of phosphoric acid in making potassium phosphate is in excess of the amount needed to absorb the potash and can be united with ammonia, giving ammonium phosphate.

It will be seen, therefore, that in the one plant there is a great possibility for the development of a complete fertilizer output by absorbing the ammonia gas of the lime-nitrogen process and the potash from the shales in phosphoric acid which is of itself a carrier of fertilizer values and then crystallizing the compounds by the application of heat, much like sugar is secured from the juice of the beet.

(c) Oxygen.

In one of the buildings at Nitrate Plant No. 2, the air is separated into two component gases, nitrogen and oxygen. The nitrogen is used in making lime-nitrogen but the oxygen is released and returns to the atmosphere. Inasmuch as this gas is used extensively in factories and shops for welding and similar uses, eventually we may expect that it will be retained and disposed of commercially.

Comment by the Committee

Although the making of phosphate and potash fertilizers at Nitrate Plant No. 2, are herein classified as possibilities, it must be conceded, by all, that not much remains to be done in an experimental way as most, if not all, the chemical problems have been solved. Their classification as possibilities rather than actualities is accounted for by the fact that No. 2 was built to make lime-nitrogen and other forms of nitrogenous products and certain additions to the equipment and perhaps some new construction would be necessary if other fertilizers were made. Whether or not such expenditures will be approved remains in doubt.

Farmers should realize, though, that the plant is abundantly justified if it produces nothing more than nitrogenous products.

That there may be a clearer understanding of the importance of the entire Muscle Shoals project, and especially that the significance of its phosphate development may be fully realized, your Committee submits herewith some quotations from an article written in July 1919, by Dr. Caro, who is recognized in Germany as the leading authority on nitrogen fixation. Dr. Caro was minister of war munitions for Germany at one time.

> "Far more dangerous (to the German nitrogen industry) than the competition of Chilean nitrate appears to be the possibility of competition with artificially fixed nitrogenous fertilizers produced in foreign countries.
>
> "The largest of these foreign lime-nitrogen plants is located in the United States in Alabama. Its situation is most excellent. It is connected with the ocean by means of the Tennessee River which has been made navigable. It is situated at a source of almost constant water-power amounting to 400,000 horse-power, and is right in the midst of a locality where all the raw materials of the lime-nitrogen (cyanamid) industry are present in the highest purity and at the very lowest prices.
>
> "Nearby are the inexhaustible deposits of high per cent phosphate rock. The possibility, therefore, exists of producing cheaply ammonium phosphate containing roughly 45 per cent of water soluble phosphoric acid and 20 per cent nitrogen.
>
> "To be sure the United States is in a position to use right there the nitrogen thus produced, amounting to about 130,000 tons per year—nevertheless it will be possible to ship it long distances to places where its phosphoric acid content will be of importance and hence it will be sure to offer very strong competition to the German fixed nitrogen industry."

IX. CONSERVATION

Nitrate Plant No. 1, Nitrate Plant No. 2, and the Wilson Dam together constitute what is probably the greatest single conservation activity of our Government. This entire project should be viewed in the same light as is an irrigation project, a forest reclamation activity, or a levee and drainage problem. Its great purpose, in peace times, is to assist in maintaining our soil fertility and consequently in the adequate production of food for our increasing millions.

As all other conservation projects are of general interest to all the citizens, so is this undertaking at Muscle Shoals. Farmers and military men need not assume to themselves all the benefits accruing from an operation of this project. In times of war it will be predominately military in type; in times of peace it will be almost wholly agricultural in character. But at all times it will be of service to all our people, to protect and to feed.

When the rapid depletion of our soil resources, especially the nitrogen content, is considered we cannot view with complacency the ultimate condition toward which we are advancing, agriculturally. An average crop of corn takes from the soil about three billion pounds of nitrogen. A cotton crop of fifteen million bales depletes the soil to the extent of one-half billion pounds of nitrogen. Other

crops take lesser amounts but the grand total will not fall below six billion pounds. Of course the alchemy of nature is working all the time in slowly replacing this lost nitrogen but the process is wholly inadequate to keep pace with the requirements of our growing crops.

Man is doing a great deal to replace what his crops take from the soil in the form of nitrogen by growing legumes, by spreading manures, and by using fertilizers. But his efforts do not more than half restore the nitrogen that the soil loses yearly. More nitrogenous fertilizers at a cheaper price would assist wonderfully in checking this soil depletion.

Comment by the Committee

In 1920 the average yield of red clover hay was, for the whole nation, 1.46 tons per acre. This hay carried enough nitrogen to yield .029 tons per acre or 58 pounds. If enough of this clover had been turned under by the plow so that all the nitrogen would have been given to the soil, it would have taken approximately four million acres to equal the annual output of Nitrate Plant No. 2. Since, however, the sacrifice of all this clover hay, at the price secured on an average for such a product, would represent a soil fertility investment of approximately sixty millions of dollars, it can be seen how significant our soil conservation problems are becoming.

X. RECOMMENDATIONS

In consideration of all the foregoing information; after personally inspecting Nitrate Plant No. 1, Nitrate Plant No. 2, the Wilson Dam, the flood area above the dam, and the construction equipment; after advising with engineers and chemists on the sites of the project; and after submitting the items of costs and estimates herein contained to other engineers and chemists of national reputation; your Committee unanimously makes two specific recommendations, as follows:

(A) THAT THE WILSON DAM BE COMPLETED BY THE GOVERNMENT WITHOUT UNDUE DELAY.

(B) THAT SINCE THE GOVERNMENT NOW HAS THE RIGHTS, UNDER CONTRACT, TO PRODUCE NITRATES BY AIR-FIXATION PROCESSES, THE NITRATE PLANTS, NO. 1 AND NO 2, SHALL BE PLACED UNDER THE DIRECTION OF A GOVERNMENTALLY OWNED CORPORATION, WHICH MAY, AT ITS DISCRETION, OPERATE THE PLANTS OR MAINTAIN THEM READY FOR OPERATION, BUT WITH STRICT REGULATIONS RELATIVE TO PRICES TO BE SECURED FOR COMMODITIES IN WHICH PRODUCTS OF THESE PLANTS ARE USED.

Comment by the Committee

In connection with the recommendations above set out your Committee offer this additional information:

Relative to Recommendation (a):

(a) That the work on the Wilson Dam is now only sufficient for maintenance.

(b) That such maintenance, or stand-by expense, is too great to be long continued.

(c) That work cannot be resumed on the Wilson Dam until Congress makes the necessary appropriation, which will be approximately $10,000,000.

(d) That the completion of the Wilson Dam is indispensable to a successful and economical operation of the nitrate plants.

(e) That since the Federal Government has invested millions of dollars at Muscle Shoals, it is nothing but good business to complete the investment by finishing the Wilson Dam so that the entire undertaking may begin to return service to the people and interest to the Treasury.

(f) That if work is too long suspended on the Wilson Dam, much of the temporary preparations for construction will not then be available but will have to be again performed.

Relative to Recommendation (b):

(a) That Nitrate Plants No. 1 and No. 2 can be operated by the Federal Government as the lessee of patent rights covering the processes used. There is herewith submitted a quotation from the contract which has been signed by the firm owning the patents and the Federal Government:

> "The licensor (the firm owning the patent rights) hereby gives and grants to the licensee (the Federal Government) in addition for use and application exclusively by the licensee in the operation of the aforesaid plants, the rights, license, and privilege to use any and all of the patents, processes, methods and designs embraced in the license hereinbefore granted to the licensee by Article 1 hereof, from and after the first day of June, 1921, or the date upon which the United States shall cease to be in the present war (whichever date shall last occur) and until the expiration of the United States patents covering the same, upon the following terms, to-wit."

(b) That the Federal Government must pay a royalty to the firms owning the patent rights on the processes for every pound of nitrogen content that is manufactured in the plants until the patents expire, which will be in most instances in 1931. Continuing the above quotation:

> "The licensee shall pay monthly to the licensor for such additional license under this article a royalty, unless and until changed by the arbitration hereinafter provided, of 1½ cents per pound of nitrogen content in any and all products manufactured by the licensee at each and every of said plants under and by the use of any of the patents, processes, methods, or designs embraced in the said additional license."

(Then follows provision for arbitration of royalty fees if either party to the contract is dissatisfied).

(c) That the nitrate plants cannot be leased by the Federal Government to any private firm, unless indeed it be the ones that own the patents on the processes used.

"The licensor for use and application exclusively by the United States Government or the aforesaid agent (the representative of the Ordnance Department who signed the contract for the Government) at such plants, has given, granted, assigned and does hereby give, grant, and assign to the licensee the right, license, and privilege to use any and all the processes, methods and designs covered by letters patent of the United States and involved in the manufacture of lime nitrogen (calcium cyanamid), its conversion to ammonia gas and the oxidation of the ammonia to weak nitric acid, etc."

(d) That, therefore, your Committee could see only three alternatives relative to the disposition of the plants, as follows:

(1) To lease them for operation; which leasing, under the contract, would necessarily be to the firms owning the patent rights, and would give us, as a primary conclusion, that no appreciable lowering of fertilizer prices would ensue.

(2) To keep the plants intact on a yearly stand-by, or maintenance, expense which would be great, ready to produce nitrogen in the event of another war, but suffering all the time an unavoidable deterioration of the present equipment and of its adaptability to the development of new processes, which might reasonably be expected to render us helpless, so far as nitrogen fixation is concerned, in comparatively a few years.

(3) To operate the plants under some sort of governmental machinery which would guarantee a business-like administration of their affairs.

(e) That your Committee chose the third method outlined above and wishes at this point to outline briefly its ideas as to the administration of the plants.

Your Committee thinks it is a universal conclusion that such establishments should not be dependent upon annual appropriations from Congress but that they should be thoroughly equipped, supplied with the necessary operating capital in the shape of a loan or otherwise, and then directed by a board which should be left free to operate the plants on a business basis.

This board should be the legal head of a corporation, the stock of which is all held by the Treasury of the United States. The members of the board should represent various occupations of our people but each member should be a person of proven business ability. It is preferred by your Committee that the members of the board be appointed by the President of the United States similar to the appointment of other Federal Boards and Commissions. After their appointment, the members of this Board should be left free, except with such limitations as are legally necessary, to direct the affairs of the entire Muscle Shoals project as a corporate entity.

The powers of this corporation for which this Board acts should be, in the opinion of your Committee, generally as follows:

(a) To own and operate the entire Muscle Shoals project;

(b) To sell to the United States, to producers and to others the products manufactured;

(c) To regulate the prices obtained for any mixtures in which products of these plants are used;

(d) To purchase, lease or acquire patents, both domestic and foreign, of improved processes;